ANALYSES AND TAXONOMIC UTILITY OF THE CEDARWOOD OILS OF THE SERRATE LEAF JUNIPERS OF THE WESTERN HEMISPHERE

Robert P. Adams
Biology Department, Baylor University, Box 727, Gruver, TX, 79040
Robert_Adams@baylor.edu

ABSTRACT

Analyses of the wood oils of the serrate leaf margined *Juniperus* of the western hemisphere (21 species, 3 varieties and 1 form) are presented. All taxa have considerable amounts of cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene. In general, there was little correlation between cedarwood oil compositions and phylogeny in this section of *Juniperus*. *Phytologia 91(1):117-139 (April, 2009).*

KEY WORDS: *Juniperus*, Cupressaceae, wood oils, taxonomy, serrate leaf, cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene.

The serrate leaf margined junipers of the western hemisphere appear to represent a natural sub-group of *Juniperus* (Adams, 2008). A phylogenetic tree (Fig. 1) shows the relationships among these junipers based on nrDNA and trnC-trnD sequences. These junipers evolved at the margins of deserts in the southwestern US and Mexico. The southwestern US - Mexico, the northern-Mediterranean, and central-Asia - western China are the three centers of biodiversity of *Juniperus*. The serrate leaf junipers appear to be the most recent species of the genus (Adams, 2008). The group is composed of: *J. angosturana* R. P. Adams, *J. arizonica* (R. P. Adams) R. P. Adams, *J. ashei* Buchholz, *J. a.* var. *ovata* R. P. Adams, *J. californica* Carriere, *J. coahuilensis* (Martinez) Gaussen ex R. P. Adams, *J. comitana* Martinez, *J. compacta* (Mart.) R. P. Adams, *J. deppeana* Steudel var. *deppeana*, *J. d.* forma *elongata* R. P. Adams, *J. d.* forma *sperryi* (Correll) R. P. Adams, *J. d.* forma *zacatacensis* (Mart.) R. P. Adams, *J. d.* var. *gamboana* (Mart.) R. P. Adams, *J. d.* var. *patoniana* (Martinez) Zanoni, *J. d.* var. *robusta* Martinez, *J. durangensis* Martinez, *J. flaccida* Schlecht., *J. grandis* R.

P. Adams, *J. jaliscana* Martinez, *J. martinezii* Perez de la Rosa, *J. monosperma* (Engelm.) Sarg., *J. monticola* Martinez forma *monticola*, *J. m.* forma *orizabensis* Martinez, *J. occidentalis* Hook., *J. osteosperma* (Torr.) Little, *J. pinchotii* Sudworth, *J. poblana* (Martinez) R. P. Adams, *J. saltillensis* M. T. Hall, and *J. standleyi* Steyermark.

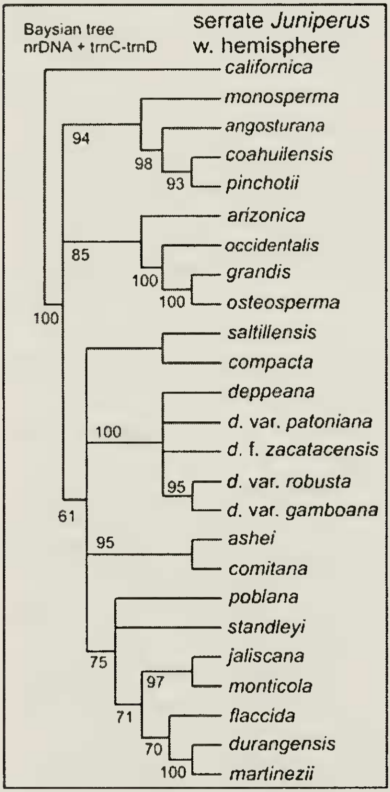


Figure 1. Phylogenetic tree of the serrate junipers (from Adams, 2008).

Although the leaf essential oils of *Juniperus* have been extensively utilized for taxonomic purposes (Adams, 1991a; Adams, 2008), the wood oils have not received much taxonomic attention. Adams (1987, Adams, 1991b) examined the wood oils of junipers from the United States as potential sources of cedarwood oil and reviewed the literature on early analyses of *Juniperus* wood oils.

Commercial cedarwood oils have been obtained from 3 genera of Cupressaceae: *Juniperus* (Texas, Virginia and African oils); *Cupressus* (China) and *Cedrus* (Morocco, India) according to Bauer and Garbe (1985). However, Texas (*Juniperus ashei* Buch.), Virginia (*J. virginiana* L.) and Chinese (putatively, *Cupressus funebris* Endl.) cedarwood oils account for almost all the cedarwood oil commercially produced today (Lawrence, 2003). The heartwood oils of the Cupressaceae are well known for having the same components across the family (i.e., evolutionally conserved), so the occurrence of similar oils in different genera is not surprising. It is probably due to the conservation of the principal commercially important components (cedrol, widdrol, cis-thujopsene, α-cedrene and

β-cedrene) that the wood oil compositions have not been utilized for taxonomic purposes.

A second reason that wood oils have not been widely utilized is the difficultly in taking samples. Leaf sampling does not harm a tree. But to obtain a wood sample requires cutting down the tree, cutting off a limb, or taking a coring sample. Taking tree cores is the least destructive, but presents a problem if steam distillation is utilized to obtain the wood oil, as a core sample consists of only a few grams of wood and the oil can easily be lost on the walls of the steam distillation apparatus. Comparison of steam distillation versus solvent extraction using wood from the same tree (*J. ashei*) is shown in Table 1. Notice that the highest yield was obtained from steam distilled wood shavings and that 24 h of pentane extraction of wood chips removed only about one- half of the oil obtained by steam distillation of wood shavings. Using finely ground wood, resulted in about the same yield as using wood chips.

Table 1. Comparison using *J. ashei* wood for yields (oven dry wt basis) and the concentrations of key components of oils obtained by steam distillation (24 h), vs. various wood chip sizes and extractions with pentane .

variable	steam distilled shavings[1]	Pentane extractions: wood chips ext'd 24 h[2]	wood from [2] re-ext'd +72h[3]	ground wood ext'd 24h[4]
per cent yield	3.7%	1.6%	1.6%	1.6%
α-cedrene	7.0	2.4	4.2	1.8
β-cedrene	1.7	1.1	2.0	1.0
cis-thujopsene	14.6	5.6	10.8	27.7
cedrol	48.1	64.3	66.1	47.2
cis-thujopsenic acid	0.6	10.4	4.8	1.1

[1]shavings obtained from original wood, then steam distilled 24 h.
[2]wood cut into 25 mm x 3 mm x 3mm wood chips, pentane extracted by shaking, 24 h. (# 9696)
[3]wood from 1st 24 h extraction ([2]), then the extracted wood chips were ground in a coffee mill and a second, 72h, pentane (# 9697) performed.
[4]original sample wood ground in coffee mill, then pentane extracted pentane for 24 h (#9700).

None of the pentane extractions gave exactly the same results as the steam distillation (Table 1). However, steam distillation can result in decomposition (Adams, 1991b), whereas solvent extraction is a very gentle method. This is shown in the marked increase of cis-thujopsenic acid in the solvent extracts (Table 1). Free acids may be dissolved in the steam condensate and return to the boiling chamber or they may decompose during distillation (Adams, 1991b). If all the wood samples are extracted in the same manner (ex. 24 h, shaking in pentane, cut to uniform sizes), solvent extraction should produce a reasonable snapshot of the profile of the wood oils.

The purpose of this paper was to present analyses of the wood oils of all the serrate junipers of the western hemisphere and evaluate these data for use as taxonomic characters.

MATERIAL AND METHODS

Samples used in the study: *J. angosturana*, 10.5 km e of Villa Juarez (road from Cerritos to Rio Verde), thence s 1.3 km, San Luis Potosi, Mexico, Lab # 9743 *Adams 8714*, *J. arizonica,* Rock Hound St. Park, Luna Co., NM, Lab # 9725, *Adams 7637*, *J. ashei*, 1.6 km e of Llano R., on I10, east of Junction, Kimble Co., TX, Lab #9721., *Adams 5010*, *J. californica*, 13 km n of I40 on road to Kelso, San Bernardino Co., CA, Lab # 9750, *Adams 5071*, *J. coahuilensis*, 32 km n of Alpine, TX, Jeff Davis Co., Lab # 9723, *Adams 4994*, *J. comitana*, 14 km s of Comitan and thence 14 km e on rd to Montebello, Chiapas, MX, Lab # 9737, *Adams 6862*, *J. compacta*, near the summit of Cerro Potosi, Nuevo Leon, MX, Lab # 9742, *Adams 6898*, *J. deppeana* var. *deppeana*, 32 km nw of Ft. Davis on Tex 118, Jeff Davis Co., Lab # 9744, *Adams 4983*, *J. d.* var. *gamboana*, 17 km n of Comitan on Mex. 190, Chiapas, MX, Lab # 9735, *Adams 6864*, *J. d.* var. *patoniana*, km 152 on Mex. 40, 52 km w of El Salto, Durango, MX, Lab # 9738, *Adams 6838*, *J. d.* var. *robusta*, west of Creel, Chihuahua, MX, Lab # 9728, *Adams 6826*, *J. d.* forma *zacatacensis*, 18 km w of Sombrerete, between km 178 & 179 on Mex. 45, Zacatecas, MX, Lab # 9740, *Adams 6840*, *J. durangensis*, nw side of Mex. 40, km 152, 52 km w of El Salto, Durango, MX, Lab # 9749, *Adams 6832*, *J. flaccida*, 20-25 km e of San Roberto Jct., on Mex. 60, Nuevo Leon, MX, Lab # 9745

Adams 6892, *J. grandis*, at Sonora Bridge Campground Rd., 2 km w of Jct of CA 108 and US 285 on CA 108, Mono Co., CA, Lab # 9734, *Adams 5061*, *J. jaliscana*, 19 km e of Mex. 200, on road to Cuale, Jalisco, MX, Lab # 9739, *Adams 6846*, *J. martinezii*, on La Quebrada Ranch, 40 km n of Lago de Moreno off Mex. 85 to Amarillo, thence 10 km e on dirt rd to La Quebrada Ranch, Jalisco, MX, Lab # 9727, *Adams 8709*, *J. monosperma*, 1.6 km w of Santa Rosa, on I40, Guadalupe Co., NM, Lab # 9748, *Adams 5028*, *J. monticola* forma *monticola*, 1 km n of jct of Mex. 105 and El Chico Natl. Park, on road to El Chico Natl. Park (8 km ne of Pachuca), Hidalgo, MX, Lab # 9747, *Adams 6874*, *J. occidentalis*, 58 km w of Juntura on US 20, Malheur Co., OR, Lab # 9724, *Adams 5085*, *J. osteosperma*, 25 km e of Monticello, on US 666, San Juan Co., UT, Lab # 9741, *Adams 5053*, *J. pinchotii* Sudw., 10 km w of Sheffield, on I10, Pecos Co., TX, Lab # 9722, *Adams 5004*, *J. poblana*, at KM 62 on Mex. 190, 62 km s of Oaxaca, Oaxaca, MX, Lab # 9729 *Adams 6871*, *J. saltillensis*, 14 km e of San Roberto Jct., on Mex. 60, Nuevo Leon, MX, Lab # 9726, *Adams 6887* and *J. standleyi*, 24 km nw of Huehuetango on road to San Juan Ixcoy (s of El Oro), Guatemala, Lab # 9746, *Adams 6852*. Vouchers are in the herbarium, Baylor University (BAYLU).

Wood samples were radially cut in 1 cm segments using a band saw. The radial sections were then cut linearly into 2 x 5 mm (x 1 cm) pieces. The wood (25 g) was placed in a 125 mL screw cap bottle to which 50 mL of pentane was added. The bottles were shaken for 24 h on a rotary shaker. The pentane extract was filtered and the pentane evaporated by use of nitrogen. The extracted wood was oven dried 48 h, 100 ^{o}C for use in the oven dry weight calculations. Percent yields were determined on an oven dry weight basis as: 100 x oil wt./(oil wt. + oven dry wood wt.). All oil samples (including commercial cedarwood oils) were dissolved in diethyl ether (10% oil solution) and stored at -20°C until analyzed.

The extracts were analyzed on a HP5971 MSD mass spectrometer operated in the EI mode, scan time 1sec., acquisition mass range: 41-500, directly coupled to a HP 5890 gas chromatograph, using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column, 0.2 μL injected of a 10 % solution in

diethyl ether, and split 1/10, injector: 220 °C, transfer and MSD: 240 °C, column temperature linearly programmed: 60° - 246 °C/ 3 °C min. Identifications were made by library searches of our volatile oil library (10), using the HP Chemstation library search routines, coupled with retention time data of authentic reference compounds. Quantitation was by use of the HP Chemstation software. Normally one would report the data as FID values, but considering the difficultly of the peaks overlapping such that quantitation involved using single ion chromatograms to estimated the concentrations (eg. cedrol/ widdrol, etc.), it was not practical to quantitate the components by GC-FID.

RESULTS AND DISCUSSION

Tables 2 and 3 show the complete analyses of the cedarwood oils of all 25 taxa of serrate leaf margined junipers of the western hemisphere. Due to the use of a liquid extraction, considerable amounts of cis-thujopsenic acid (and other acids) were present in the extracts. It appears much of the cis-thujopsenic acid is degraded or left in the water condensate during steam distillation (Table 1). Although most taxa have considerable amounts of cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene, there are many un-identified sesquiterpenoids. However, it is surprising to find such a large number of un-identified compounds. Often, an un-identified compound was present in only one or twice taxa. It appears that there may be considerable synthesis of non-specific products in the wood. Keeling and Bohlmann (2006) discuss the defense nature of terpenoids and note that maintaining a diverse array of chemicals may be effective as a plant defense.

The major components useful in commercial cedarwood oils are cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene. Table 4 shows the compositions of these five constituents in the 25 taxa of this study. Notice that even in phylogenetically similar taxa (Figure 1, *arizonica, occidentalis, grandis* and *osteosperma*), there is considerable variation in the amounts of these components. In fact, it seems that there is as much variation among these presumably closely related species as among other more distantly related species (Table 4).

The sum of cedrol, widdrol, cis-thujopsene, α-cedrene and β-cedrene gives one some indication of the oils' utility as cedarwood oil. The sums range from 22% of the total oil (*J. jaliscana*, Table 4) to 70.4% *(J. angosturana*, Table 4). The species with low sums generally have considerable amounts of unknown compounds. The percent yields ranged from 0.04% (*J. deppeana* var. *patoniana*) to 3.4% (*J. standleyi*). As a reference, the source of Texas cedarwood oil, *J. ashei*, had a 1.7% oil yield. The product of the sum of the key components x % yield (S x %, Table 4) is an index to the relative commercial potential of a species. This index varied from 2.0 (*J. deppeana* var. *patoniana*) up to 169.4 for *J. angosturana* with *J. ashei* having an index value of 104.9. Although *J. angosturana* (169.4), *J. d.* var. *gamboana* (128.6) and *J. standleyi* (143.1), all from Mexico, scored higher than *J. ashei* from the United States (mostly Texas), they are generally not found in large enough populations to sustain continued harvest of trees for cedarwood oil. *Juniperus arizonica, J. californica, J. grandis, J. monosperma, J. occidentalis* and *J. pinchotii* are weedy, widespread junipers of the western US but these are either lacking a high concentration of the key compounds or their percent yields are low and do not appear suitable for commercial cedarwood oil production.

In conclusion, the cedarwood oils in this section of *Juniperus* do not seem to be useful to taxonomy at the specific level. It would be interesting to examine geographic variation within a species to determine if the wood oils might be useful for populational studies.

ACKNOWLEDGEMENTS

Thanks to Tom Zanoni and Glenn Harris for assistance on the field trips in Mexico and Guatemala. This research supported in part by funds from Baylor University.

LITERATURE CITED

Adams, R. P. 1987. Investigation of *Juniperus* species of the United States for new sources of cedar wood oil. Econ. Bot. 41: 48-54.

Adams, R. P. 1991a. Analysis of Juniper and other forest tree oils. pp. 131-157. In: Modern Methods of Plant Analysis, New Series: Oil and Waxes. H.-F. Linskens and J. F. Jackson, eds. Springler-Verlag, Berlin.

Adams, R. P. 1991b. Cedarwood oil - Analysis and properties. pp. 159-173. In: Modern Methods of Plant Analysis, New Series: Oil and Waxes. H.-F. Linskens and J. F. Jackson, eds. Springler- Verlag, Berlin.

Bauer, K. and D. Garbe. 1985. Common fragrance and flavor materials. CVH Verlagsgesellschaft, Weinheim, Germany.

Keeling, C. and J. Bohlmann. 2006. Genes, enzymes and chemicals of terpenoid diversity in the constitutive and induced defence of conifers against insects and pathogens. New Phytologist 170: 657-675.

Lawrence, B. M. 2003. Essential Oils 1995-2000. Allured Publ., Carol Stream, IL.

Table 2. Composition of cedarwood oils from the serrate leaved *Juniperus*. cailf = *J. californica*, mono = *J. monosperma*, ango = *J. angosturana*, coah = *J. coahuilensis*, pine = *J. pinchotii*, ariz = *J. arizonica*, occi = *J. occidentalis*, gran = *J. grandis*, oste = *J. osteosperma*, salt = *J. saltillensis*, comp = *J. compacta*.

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1178	naphthalene	0.4	0.6	0.1	0.1	4.3	0.1	0.1	0.4	0.3	0.1	0.1
1186	α-terpineol	-	-	-	-	-	-	-	-	-	-	0.1
1232	thymol methyl ether	-	-	-	-	0.2	-	-	t	-	-	-
1387	α-duprezianene	1.0	-	0.1	-	0.4	0.4	t	0.1	t	0.1	0.1
1390	7-epi-sesquithujene	-	-	0.1	0.2	-	-	-	t	-	-	-
1400	β-longipinene	-	-	-	-	-	t	-	-	-	-	-
1402	α-funebrene	-	-	-	-	-	-	-	-	-	t	-
1405	sesquithujene	-	-	-	0.1	-	-	-	-	-	-	-
1410	α-cedrene	1.2	0.7	1.4	1.1	3.6	1.9	0.9	1.4	1.3	1.2	0.4
1411	2-epi-β-funebrene	-	-	-	-	-	-	-	-	-	-	0.3
1413	β-duprezianene	1.3	-	-	-	-	0.6	-	-	-	t -	0.3
1419	β-cedrene	0.6	0.5	0.7	0.5	1.6	0.6	0.8	0.9	0.7	0.7	0.4
1429	cis-thujopsene	2.2	9.0	17.5	18.4	12.0	14.5	6.4	15.4	13.7	9.0	2.5
1436	isobazzanene	-	-	-	-	-	-	-	-	-	t	-
1449	α-himachalene	-	-	0.2	0.3	-	0.3	t	0.2	t	0.1	-
1454	(E)-β-farnesene	-	-	0.2	-	-	-	-	-	-	-	-
1464	thujopsadiene	0.2	0.6	-	0.8	0.6	0.7	0.2	0.4	0.3	0.4	0.1
1464	α-acoradiene	-	-	0.2	0.1	-	-	-	-	-	-	-
1469	β-acoradiene	-	-	-	-	t	-	-	-	-	-	-
1470	10-epi-β-acoradiene, isomer	-	-	t	-	-	-	-	-	-	-	-
1479	β-chamigrene	0.2	0.3	-	0.3	0.3	t	0.2	-	-	0.2	-

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1479	ar-curcumenene	-	-	-	0.1	-	-	0.1	-	-	-	-
1481	γ-himachalene	-	-	0.2	-	-	0.5	-	0.3	0.2	-	-
1485	11-αH-himachala-1,4-diene	-		-	-	0.5	-	-	-	-	-	-
1489	β-selinene	0.6	-	-	-	-	-	0.1	0.2	-	-	0.1
1498	β-alaskene	-	-	-	0.1	-	-	-	-	-	-	-
1498	α-selinene	-	-	-	-	-	0.3	0.2	0.1	-	-	-
1499	pseudowiddrene	-	-	-	-	-	0.5	-	0.1	0.2	0.3	-
1500	β-himachalene	0.4	-	0.7	0.3	0.9	0.4	-	0.2	0.2	-	-
1502	trans-β-guaiene	-	0.2	-	-	-	-	-	-	-	-	-
1503	α-chamigrene	-	-	-	-	-	t -	t	0.1	-	1.7	-
1504	cuparene	4.8	1.3	0.3	1.2	2.4	1.7	0.9	1.4	1.1	1.2	0.8
1512	α-alaskene	-	-	0.1	0.2	-	0.5	-	0.2	t	0.1	-
1514	butylated hydroxy toluene*	-		-	-	1.3	-	-	t	t	-	-
1521	trans-calamenene	-	0.5	-	-	0.7	0.3	t	t	t	t	-
1522	δ-cadinene	-	-	-	-	-	-	0.2	t	-	-	-
1532	γ-cuprenene	-	-	0.3	-	-	-	-	-	-	-	-
1536	italicene ether	0.3	0.5	-	0.3	-	-	-	t	-	0.4	-
1540	sesquiterpenol <u>43</u>,44,95,220	-	-	-	0.6	-	-	-	-	-	-	-
1541	sesquiterpenol <u>43</u>,97,205,220	-	-	-	-	-	1.3	-	-	-	-	-
1541	8,14-cedranoxide	0.3	0.8	-	-	0.5	-	-	-	-	-	-
1542	δ-cuprenene	-	-	0.1	-	-	-	0.3	0.1	t	-	-
1546	elemol	-	0.2	-	0.6	-	-	-	-	-	-	-
1562	longicamphenylone	-	-	-	-	-	-	-	-	-	-	0.2
1582	caryophyllene oxide	-	0.3	-	0.4	0.4	-	0.1	-	-	-	-
1589	allo-cedrol	2.2	1.7	0.9	2.0	1.4	1.0	0.9	1.2	1.0	1.0	4.1

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1595	cis-dihydro-mayurone	0.5	t	-	-	0.1	0.3	0.3	0.2	0.3	0.2	-
1599	widdrol	11.7	7.1	t	-	4.2	7.6	t	-	t	t	-
1600	cedrol	11.7	14.1	51.0	17.4	38.6	3.1	43.3	41.8	36.3	46.9	54.2
1612	β-biotol	0.6	1.3	0.5	0.5	t	-	t	0.4	-	0.3	-
1618	epi-cedrol	-	-	0.6	0.6	0.4	t	1.2	1.1	0.3	0.3	1.3
1622	sesquiterpenol 111,43,69,220	-	-	-	0.6	-	-	-	-	-	-	-
1634	α-acorenol	0.8	5.7	3.6	5.9	3.2	3.4	4.0	3.1	3.1	6.8	0.7
1636	β-acorenol	0.7	1.8	0.8	1.6	1.2	0.9	1.0	0.8	0.8	1.3	0.4
1639	1,7-di-epi-α-cedrenal	-	-	-	-	-	-	-	-	-	-	0.5
1641	3-iso-thujopsanone	0.8	-	-	-	-	-	-	0.3	-	-	-
1648	sesquiterpenol 119,43,204,220	-	-	-	1.7	-	-	-	0.9	-	0.5	-
1649	sesquiterpenol, 43,119,71,220	-	1.5	0.8	-	1.9	-	0.9	-	-	-	-
1649	β-eudesmol	1.8	6.9	0.6	3.2	0.2	-	0.4	-	3.7	-	-
1652	α-eudesmol	-	1.4	-	1.4	t	-	-	-	1.5	-	-
1658	selin-11-en-4α-ol	1.3	-	-	-	-	-	0.7	-	-	0.9	-
1660	sesquiterpen-ol 135,79,220	-	-	0.8	-	-	-	-	-	-	-	-
1662	sesquiterpenal 43, 123, 236	4.1	-	-	-	-	-	-	2.3	-	-	-
1663	sesquiterpenal 135,91,69,236	-	-	-	-	-	2.2	2.0	-	-	-	1.9
1665	intermedeol	-	-	-	-	0.6	-	-	-	-	-	-
1665	sesquiterpenal 43,123,95,236	-	3.2	-	1.6	1.9	-	-	-	-	-	-
1666	sesquiterpenal 43,69,135,236	-	-	-	-	-	-	-	-	1.9	-	-
1666	sesquiterpenol 119,41,93,220	-	-	0.7	-	-	-	-	-	-	-	-
1667	sesquiterpenol 105,91,119,218	-	-	-	-	-	4.4	1.4	-	-	-	-
1668	sesquiterpenol 41,69,91,220	-	-	-	0.7	-	-	-	-	-	-	-
1675	cadalene	0.3	-	-	-	-	-	-	-	-	-	-

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1683	epi-α-bisabolol	-	1.5	0.2	0.5	0.4	-	0.6	0.5	-	-	-
1685	α-bisabolol	-	-	0.2	0.5	-	-	0.1	t	-	-	-
1688	8-cedren-13-ol	-	-	-	-	3.2	-	-	0.4	1.1	-	0.4
1689	sesquiterpenol <u>43</u>,121,132,222	-	-	-	-	-	-	-	-	-	-	0.8
1692	junicedranol	-	0.8	-	-	-	-	-	-	-	-	-
1694	sesquiterpenol, <u>41</u>,91,135,220	2.5	-	-	-	-	-	-	-	-	2.6	-
1699	sesquiterpenol <u>135</u>,79,105,220	-	1.5	3.6	4.0	-	3.7	-	2.6	3.5	-	1.0
1701	cis-thujopsenol	-	4.3	4.8	4.4	-	-	-	2.4	2.5	2.6	-
1703	mayurone	18.5	4.3	-	-	3.5	-	-	-	-	-	1.2
1708	cis-thujopsenal	-	-	-	1.1	-	-	-	-	1.7	2.5	-
1709	sesquiterpenal <u>123</u>,41,218	3.2	2.3	-	-	1.5	0.9	-	0.8	-	-	-
1714	sesquiterpene <u>43</u>,135,207232	4.2	2.7	-	-	1.2	-	-	-	-	-	0.4
1716	sesquiterpenol <u>43</u>,135,207,222	-	-	-	1.1	-	-	-	-	-	-	-
1724	(Z)-nuciferol	-	-	-	-	-	-	-	-	1.1	-	-
1726	sesquiterpenal <u>43</u>,137,218,236	2.8	2.2	-	-	0.5	-	-	t	-	-	-
1729	sesquiterpenal <u>119</u>,147,162,236	-	-	-	2.3	-	-	1.6	t	-	-	0.4
1748	sesquiterpenal <u>123</u>,55,41,234	-	1.0	-	-	-	-	-	-	-	-	-
1751	sesquiterpenol <u>105</u>,41,147,220	-	-	0.8	-	-	-	1.1	-	1.0	-	-
1751	cuparenal	0.8	0.8	-	-	0.4	-	-	-	-	-	-
1762	β-acoradienol	4.6	- -	0.5	-	-	1.2	-	0.5	-	0.8	0.7
1765	β-costol	-	-	-	-	-	-	-	0.3	0.3	-	0.5
1766	sesquiterpenal <u>41</u>,55,107,234	-	1.7	-	-	0.6	-	-	0.2	-	-	-
1773	α-costol	0.4	-	-	-	-	-	0.6	-	-	-	-
1789	sesquiterpenol <u>123</u>,41,135,220	-	-	0.6	-	-	-	-	-	-	-	-
1793	sesquiterpenal <u>189</u>,43,207,236	-	-	-	4.8	-	-	0.5	-	-	-	-

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1796	sesquiterpenal 148,131,41,218	-	-	-	-	0.7	2.8	0.6	0.6	-	-	-
1797	sesquiterpenal 43,189,207,236	-	3.1	-	-	-	-	-	-	1.2	-	2.8
1801	sesquiterpene 95,91,171,232	1.3	-	-	-	-	-	-	-	-	-	-
1802	sesquiterp..ol 121,136,177,220	-	-	1.8	1.1	0.6	0.8	1.0	0.8	0.6	1.4	0.5
1805	sesquiterpenal 121,136,177,234	-	0.8	-	-	-	-	-	-	-	-	-
1810	sesquiterpenal 55,135,234	0.8	-	-	-	-	-	-	-	-	-	-
1813	cryptomeridiol	-	0.6	0.3	0.8	-	-	-	-	0.5	-	-
1815	sesquiter. acid 149,91,105,234	1.0	-	-	-	-	1.0	0.5	1.3	-	1.3	-
1831	sesquiterpenol 91,105,135,220	-	-	0.5	-	-	-	-	-	-	-	-
1836	sesquiterpene 43,119,190	0.7	-	-	-	-	-	-	-	-	-	-
1837	sesquiterpene 119,161,43,191	-	-	-	-	-	2.1	-	-	-	-	-
1863	cis-thujopsenic acid	1.7	3.6	0.9	1.8	0.7	6.7	5.9	5.5	6.6	5.8	0.1
1889	cedrane-8S,14-diol	2.2	1.8	-	3.1	-	-	2.7	2.1	2.7	-	15.2
1897	cedrane-8S,13-diol	-	t	-	1.0	-	-	-	0.3	0.1	-	0.7
1911	sesquiterpenal 41,123,211,234	1.6	-	-	-	-	-	-	-	-	-	-
1917	sesquiterpenal 41,123,149,234	-	3.0	-	0.6	-	-	-	0.5	-	-	-
1929	sesquiterpenal 121,136,191,234	-	-	-	-	-	-	0.7	0.8	0.7	1.1	-
1932	cuparenic acid	0.6	-	-	-	-	-	-	-	-	-	-
1945	sesquiterpenal 121,136,191,234	-	-	-	-	-	1.4	0.8	1.4	-	1.6	0.6
1953	sesquiterpene 43,135,181,256	2.4	-	-	-	-	-	-	-	-	0.7	-
1959	nootkatin	-	-	-	1.8	-	-	-	-	-	-	-
1959	sesquiterpene 135,43,181,256	-	1.4	-	-	-	-	-	-	-	-	-
1960	sesquit. acid 121,136,191,234	-	-	-	-	-	-	-	-	1.5	-	-
1962	sesquiterp. acid 41,43,135,256	-	-	-	-	-	-	-	0.8	-	-	-

AI	Compound	calif	mono	ango	coah	pinc	ariz	occi	gran	oste	salt	comp
1964	sesquiterp. acid 135,43,163,234	-	-	-	1.1	-	5.3	-	-	-	-	-
2158	octadecanoic acid	t	-	-	-	-	-	-	-	-	-	-
2331	trans-ferruginol	-	-	-	-	-	-	-	0.1	-	-	0.4

For unknown cpds., base ion (100%) is underlined, next ions are major ions, *butylated hydroxy toluene is normally considered a non-natural product, RI = Arithmetic Index on DB-5 (= SE54). column. Compositional values less than 0.1% are denoted as traces (t). Unidentified components less than 0.5% are not reported.

Table 3. Composition of cedarwood oils from serrate leaves *Juniperus*. depp = *J. deppeana*, dpat = *J. d.* var. *patoniana*, dzac = *J. d. f. zacatacensis*, drob = *J. d.* var. *robusta*, dgam = *J. d.* var. *gamboana*, ashe = *J. ashei*, comt = *J. comitiana*, pobl = *J. poblana*, stan = *J. standleyi,* jali = *J. jaliscana*, mont = *J. monticola*, flac = *J. flaccida*, dur = *J. durangensis*, mart = *J. martinezii.*

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
932	α-pinene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
969	sabinene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
1024	limonene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1
1178	naphthalene	0.4	1.4	0.6	0.3	0.1	0.1	0.1	0.1	0.4	0.1	0.2	0.2	0.3	0.1
1298	carvacrol	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
1380	2-epi-α-funebrene	0.1	-	0.1	-	-	-	-	-	0.1	-	-	-	-	-
1387	α-duprezianene	0.3	0.1	0.4	0.2	0.1	-	t	0.1	-	-	0.2	0.1	0.2	0.2
1389	β-elemene	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-
1390	7-epi-sesquithujene	-	-	t	-	-	-	-	-	0.1	-	-	-	-	-
1400	β-longipinene	-	-	0.1	0.1	t	-	-	-	-	-	-	-	-	-
1402	α-funebrene	-	-	-	t	-	t	-	-	-	-	-	-	-	-
1405	sesquithujene	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-
1410	α-cedrene	7.6	1.5	4.1	3.9	2.5	0.6	0.5	3.3	2.6	2.6	1.9	3.5	1.2	2.0
1413	β-duprezianene	-	t	-	t	-	-	-	-	-	0.6	t	-	-	-
1417	(E)-caryophyllene	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-
1419	β-cedrene	2.0	0.8	1.4	0.9	1.0	0.4	0.2	0.9	1.2	0.7	0.9	1.0	0.9	0.9
1424	sesquiterpene 107,131,187,202	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-
1429	cis-thujopsene	9.1	7.2	10.3	6.3	5.5	12.0	2.9	6.6	10.3	7.6	14.3	4.8	7.9	6.8
1436	isobazzanene	-	-	t	-	-	-	-	-	0.1	-	-	-	-	-

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1449	α-himachalene	0.2	-	t	0.1	-	0.1	-	-	-	0.1	-	0.1	-	-
1454	(E)-β-farnesene	-	-	t	-	-	-	-	-	-	-	-	-	-	-
1464	thujopsadiene	-	0.6	0.1	-	-	0.3	0.2	0.1	-	0.2	0.3	0.1	0.2	0.3
1464	α-acoradiene	1.1	-	0.6	0.6	t	-	-	0.3	0.7	0.1	0.3	0.1	0.2	-
1469	β-acoradiene	0.3	-	0.5	0.2	t	-	-	0.1	0.1	-	t	t	-	0.1
1476	β-chamigrene	-	0.3	0.7	0.4	0.2	-	-	0.1	-	0.4	0.3	t	t	0.3
1479	ar-curcumenene	-	-	-	0.2	-	t	-	0.1	-	-	-	t	-	0.1
1481	γ-himachalene	0.3	-	t	-	-	0.3	-	-	-	-	-	-	-	-
1485	11-αH-himachala-1,4-diene	-	-	-	-	-	-	t	-	-	-	-	-	-	-
1489	β-selinene	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-
1498	β-alaskene	0.2	-	-	0.1	-	-	-	t	-	t	-	-	-	-
1498	α-selinene	-	-	0.7	-	-	-	0.4		-	-	-	-	-	-
1499	pseudowiddrene	0.6	-	0.7	-	-	0.2	-	0.6	-	0.7	0.5	-	-	0.4
1500	β-himachalene	0.5	0.4	-	1.2	0.5	0.2	0.2	-	0.4	0.6	-	0.6	0.4	0.5
1503	α-chamigrene	t	-	t	t	-	t	-	t	0.2	0.2	t	-	-	t
1504	cuparene	1.6	1.3	2.1	1.2	0.8	1.2	0.3	1.1	0.6	1.0	1.0	1.0	3.0	0.8
1512	α-alaskene	0.7	-	0.4	0.5	0.1	0.1	-	-	0.2	0.3	0.2	0.2	-	0.2
1513	γ-cadinene	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
1514	butylated hydroxy toluene*	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-
1520	7-epi-α-selinene	-	-	-	-	-	t	-	-	-	-	-	-	-	-
1521	trans-calamenene	0.1	0.3	-	0.5	0.1	0.1	0.1	0.1	-	-	-	0.1	-	-
1522	δ-cadinene	-	-	-	-	-	0.1	0.1	-	-	-	-	-	-	0.1
1532	γ-cuprenene	0.1	-	-	-	-	-	-	-	0.1	0.1	-	-	-	0.3
1536	italicene ether	-	0.5	-	-	-	-	-	-	-	-	0.1	-	0.7	-

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1541	sesquiterpenol 43,97,205,220	-	0.8	1.1	-	-	-	-	-	-	-	-	-	-	-
1542	sesquiterpenol 43,95,164,207	-	-	-	-	0.7	-	-	-	-	-	-	-	-	-
1542	sesquiterpenol 43,55,69,222	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-
1541	8,14-cedranoxide	-	-	-	-	-	-	-	0.1	-	0.7	0.1	-	0.2	-
1542	δ-cuprenene	-	-	-	-	-	0.1	-	-	-	-	-	-	-	0.2
1582	caryophyllene oxide	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-
1586	thujopsen-2α-ol	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-
1589	allo-cedrol	0.3	1.0	0.3	0.3	0.5	1.4	1.2	0.3	1.0	0.3	1.0	0.4	2.0	0.6
1595	cis-dihydro-mayurone	0.1	0.3	0.5	0.2	0.2	t	-	0.3	0.2	0.5	0.4	0.3	0.4	-
1599	widdrol	12.0	10.0	16.0	15.6	0.1	12.0	-	20.6	25.2	10.0	7.0	32.0	5.0	3.7
1600	cedrol	25.7	30.4	1.3	2.0	55.2	36.7	43.2	21.0	2.8	1.1	10.4	15.9	21.9	34.0
1612	β-biotol	0.4	0.5	-	0.2	-	-	0.9	-	-	-	-	0.5	-	-
1615	β-himachalene oxide	-	-	-	0.2	-	-	-	0.3	-	0.2	-	-	-	-
1618	epi-cedrol	1.2	0.7	-	0.5	0.4	0.5	-	0.6	0.8	0.2	1.2	1.4	0.8	1.1
1622	sesquiterpenol 85,43,111,204	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-
1623	sesquiterpenol 43,111,69,207	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-
1634	α-acorenol	3.7	3.4	1.2	3.3	1.6	4.9	1.2	2.1	19.7	0.8	4.3	1.3	3.6	2.3
1636	β-acorenol	1.6	1.1	0.9	1.4	0.7	2.0	0.4	1.0	3.2	0.4	1.6	1.0	1.1	1.0
1638	sesquiterpenal 135,41,79,236	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-
1640	epi-α-muurolol	-	-	-	-	-	-	0.5	0.2	-	0.2	-	0.4	-	0.7
1640	sesquiterpene 41,171,48,161	-	-	-	-	-	-	-	-	-	-	-	-	0.8	-
1648	sesquiterpenol 119,43,204,220	-	-	-	-	0.3	2.7	-	0.2	-	-	-	-	-	-
1649	sesquiterpenol 43,119,71,220	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-
1649	β-eudesmol	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1650	sesquiterpenol 41,59,91,220	-	-	0.7	-	-	-	-	-	0.4	0.7	-	-	-	-
1650	cedr-8(15)-en-10-ol	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-
1652	α-cadinol	-	-	-	-	-	0.3	0.9	-	-	-	-	-	-	-
1652	himachalol	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-
1652	sesquiterpenol 41,69,107,220	-	-	-	0.9	-	-	-	-	-	-	-	-	-	2.0
1653	3-thujopsanone	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-
1658	selin-11-en-4α-ol	0.3	0.8	-	0.3	0.2	-	-	-	-	-	-	-	-	-
1660	sesquiterpen-ol 135,79,220	-	-	-	-	1.3	-	-	-	-	0.9	-	-	-	-
1661	sesquiterpenal 135,41,91,218	-	-	1.2	-	-	-	-	-	-	-	-	-	-	1.4
1662	sesquiterpenal 43,123,218,236	-	0.7	-	-	-	-	-	-	-	-	-	-	2.6	-
1662	sesquiterpenal 135,79,91,236	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-
1663	sesquiterpenal 41,79,81,236	-	-	-	-	-	-	1.4	-	-	-	-	-	-	-
1664	sesquiterpenal 41,135,79,236	0.7	-	-	1.1	-	-	-	0.6	1.1	0.8	2.4	-	-	-
1664	sesquiterpenal 41,157,218	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-
1664	junicedranone	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
1665	intermedeol	-	-	-	-	-	1.3	-	-	-	-	-	-	-	-
1665	sesquiterpenal 43,123,95,236	-	-	-	-	-	1.6	-	-	-	-	-	-	-	-
1666	sesquiterp..al 157,143,105,218	-	-	-	-	-	-	7.0	-	-	-	-	-	-	-
1668	14-hydroxy-9-epi-(E)-caryophyllene	-	-	-	-	1.4	-	-	-	-	-	-	-	-	0.8
1668	sesquiterpenol 41,119,91,220	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-
1683	epi-α-bisabolol	-	-	-	0.3	-	0.7	-	-	-	-	-	-	-	-
1685	α-bisabolol	-	-	-	0.4	-	0.1	-	-	-	-	-	-	-	-
1688	8-cedren-13-ol	0.1	-	-	4.2	-	-	-	4.2	-	9.5	0.9	1.4	-	1.4

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1689	sesquiterpenol 43,121,132,222	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-
1694	sesquiterpenal 135,71,41,220	-	-	-	-	-	-	-	-	2.9	-	-	-	-	-
1699	sesquiterpenol 135,79,105,220	1.4	2.6	5.1	4.5	4.8	0.8	1.1	5.5	-	5.4	4.1	5.7	3.0	4.1
1700	sesquiter..al 107,91,119,218	-	-	-	-	-	-	6.8	-	-	-	-	-	-	-
1701	cis-thujopsenol	-	-	-	3.8	2.5	4.4	1.4	2.6	4.0	-	-	2.3	-	2.8
1703	mayurone	1.5	5.8	1.4	-	-	-	-	-	-	-	3.8	-	9.7	-
1708	cis-thujopsenal	-	-	-	-	-	2.2	-	-	-	2.3	-	-	-	-
1709	sesquiterpenal 123,41,218,220	1.3	1.2	2.2	1.8	2.1	-	-	-	-	0.5	1.4	1.6	1.1	0.5
1714	sesquiterpene 43,135,207,232	-	2.2	0.8	0.7	-	-	-	-	-	0.3	-	-	4.1	-
1714	sesquiterpenal 123,55,206,236	-	-	-	-	-	-	-	1.2	-	-	-	-	-	-
1716	sesquiterpenol 43,135,207,222	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1724	(Z)-nuciferol	-	-	-	-	-	-	-	0.5	-	-	1.3	-	-	-
1726	sesquiterpenal 43,137,218,236	-	-	-	-	-	-	-	-	-	-	-	-	0.5	-
1729	sesquiter..al 119,147,162,236	-	-	-	-	-	-	-	-	-	-	-	2.0	-	1.2
1736	sesquiterpenal 43,123,132,218	-	-	-	-	-	-	-	-	-	-	-	-	0.6	-
1745	γ-costol	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-
1751	sesquiterpenol 105,41,147,220	0.4	-	0.8	1.4	1.5	-	-	-	-	0.7	-	1.2	-	-
1751	cuparenal	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-
1753	sesquiterpenol 105,41,79,222	-	-	-	-	-	-	-	-	2.4	-	-	-	-	-
1759	sesquiterpenal 119,93,238	0.5	-	1.2	-	-	-	-	-	-	-	-	-	-	-
1762	β-acoradienol	-	-	-	-	-	0.9	-	1.3	-	-	0.9	-	-	0.9
1765	β-costol	-	-	-	-	-	0.6	2.9	-	-	-	-	-	-	-
1766	sesquiterpenal 41,55,107,234	-	1.4	-	-	-	-	-	-	-	-	0.3	-	3.9	-
1771	sesquiterpenal 119,93,160,234	-	-	1.6	1.7	-	-	-	-	-	0.5	-	-	-	-

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1773	α-costol	-	0.5	-	-	-	0.2	1.8	-	-	-	-	-	-	-
1774	sesquiterpenal 91,41,69,235	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-
1779	14-hydroxy-α-muurolene	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6
1781	sesquiterpenal 119,93,234	-	-	-	0.6	-	-	-	-	-	1.8	-	-	-	-
1784	sesquiterp..al 159,119,220,234	-	-	-	-	-	-	-	-	-	0.9	-	-	-	-
1785	sesquiterp..al 121,136,41,218	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-
1787	sesquiterp..al 119,93,234	-	-	-	-	-	-	-	-	-	0.6	-	-	-	-
1793	sesquiterpenal 189,91,133,234	-	-	-	2.5	1.3	-	-	1.0	-	-	-	1.3	-	0.5
1793	sesquiterpenal 189,43,207,236	-	-	1.9	-	-	-	-	-	-	3.9	-	-	-	-
1793	sesquiterpenal 41,55,79,232	-	1.2	-	-	-	-	-	-	-	-	-	-	-	-
1794	sesquiterpenal 91,79,105,218	-	-	-	-	-	-	1.9	-	-	-	-	-	-	-
1796	sesquiterpenal 148,131,41,218	-	-	-	-	0.4	2.0	-	1.7	-	-	-	-	-	-
1797	sesquiterpenal 43,189,207,236	-	-	-	-	-	-	-	-	-	-	0.6	-	1.3	-
1799	sesquiterp..al 189,148,165,236	-	-	-	2.4	-	-	-	-	-	-	-	-	-	-
1802	sesquiterp..ol 121,136,177,220	-	0.7	1.1	-	1.4	1.9	0.6	2.1	1.9	-	-	1.8	0.5	0.8
1803	sesquiterp..al 189,121,43,236	-	-	-	-	-	-	-	-	-	3.9	-	-	-	-
1805	sesquiterpenal 121,136,177,234	1.0	-	-	5.4	-	-	-	-	-	-	-	-	-	-
1806	nootkatone	-	-	-	-	-	-	1.0	-	-	-	-	-	-	-
1810	sesquiterpenal 41,91,95,234	-	-	-	-	-	-	4.1	-	-	-	-	-	-	-
1815	sesquiter. acid 149,91,105,234	3.0	0.5	0.9	-	-	-	-	-	-	-	2.2	-	-	-
1821	sesquiterpenal 123,43,205	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-
1821	sesqui..acid 149,105,191,234	-	-	-	1.1	-	-	-	-	-	-	-	1.0	-	-
1837	sesquiterpene 119,161,43,191	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-
1863	cis-thujopsenic acid	7.1	2.3	17.8	8.3	4.4	2.1	0.4	6.0	2.4	5.4	11.0	5.6	1.4	6.4

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1880	sesquiterpenal 43,55,93,236	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-
1883	sesquiterp..al 105,147,219,234	0.9	-	1.2	-	0.2	-	-	-	0.8	-	-	-	-	-
1889	sesquiterp..al 119,43,132,234	-	-	-	-	-	-	1.3	-	-	-	-	-	-	-
1889	cedrane-8S,14-diol	0.6	3.9	-	0.9	-	0.3	1.3	1.4	2.7	5.4	6.9	0.7	5.5	-
1897	cedrane-8S,13-diol	-	-	-	-	-	-	-	-	-	2.4	-	-	-	-
1905	sesquiterp..al 105,147,191,234	-	-	-	-	-	-	-	0.8	-	-	-	-	-	-
1910	sesquiterp..al 149,105,91,234	-	-	-	0.8	-	-	-	0.6	-	-	-	-	-	-
1917	sesquiterpenal 41,123,149,234	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-
1919	sesquiterpenal 43,68,105,234	-	-	-	-	-	-	-	-	-	0.8	-	-	-	-
1923	sesquiterpenal 123,41,201,234	-	0.9	-	-	-	-	-	-	-	-	-	-	-	-
1925	sesquiterp..al 123,136,191,234	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-
1928	sesquiterp..al 121,41,135,234	-	-	-	-	-	-	-	-	4.4	-	-	-	-	-
1929	sesquit..acid 121,136,191,234	1.0	-	2.5	2.2	0.4	0.5	-	-	-	-	-	-	-	-
1932	sesquiterp..al 105,173,191,234	-	-	-	-	-	-	-	-	-	1.2	-	-	-	-
1941	sesquiterp..al 43,135,162,234	-	-	-	-	-	-	1.2	-	-	-	1.2	-	-	-
1944	sesquit..acid 41,91,121,234	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-
1945	sesquit..acid 121,136,191,234	1.6	-	3.7	2.7	1.4	0.3	-	1.4	2.0	1.7	1.2	0.7	0.7	-
1946	sesquiterp..al 135,43,121,234	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
1948	sesquiterp..al 158,157,143,234	-	-	-	-	-	-	2.6	-	-	-	-	-	-	-
1953	sesquiterpene 43,135,181,256	-	-	8.0	-	-	-	-	-	1.0	-	-	-	-	-
1953	sesquit. acid 135,43,181,234	-	-	-	-	-	-	-	-	-	-	-	-	3.0	-
1959	nootkatin	-	-	-	-	-	-	0.9	-	-	-	-	-	-	-
1958	sesquit. acid 121,136,191,232	-	-	-	-	-	-	-	2.8	-	-	-	-	-	-
1960	sesquit. acid 121,136,191,234	-	-	-	3.4	-	-	-	0.5	-	1.5	-	1.1	-	1.3

AI	Compound	depp	dpat	dzac	drob	dgam	ashe	comt	pobl	stan	jali	mont	flac	dur	mart
1984	sesquit..acid 135,43,181,256	-	-	-	-	-	-	-	-	-	11.6	4.7	-	-	-
2077	sesquiterp..al 59,149,105,234	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-
2082	sesquiterpene 43, 202/203,234	-	-	-	0.7	-	-	-	-	-	-	-	-	-	-
2141	oleic acid	-	-	-	-	-	-	-	-	-	-	-	-	-	2.7
2158	octadecanoic acid	-	-	-	-	-	-	-	-	-	-	-	-	-	5.0
2269	sandaracopimarinol	-	0.2	-	-	-	-	-	t	-	-	-	-	-	-
2314	trans-totarol	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-
2331	trans-ferruginol	0.2	0.2	-	0.2	-	-	0.4	0.3	0.3	-	t	0.2	-	-

Table 4. Comparison of the major oil components among taxa. ACDR = α-cedrene, BCDR = β-cedrene, THJP = cis-thujopsene, WDRL = widdrol, CDRL = cedrol, CTJA = cis-thujopsenic acid. %yld = % yield on oven dry wt basis (oil/(extracted wood, dried 48h, 100°C).

	ACDR	BCDR	THJP	WDRL	CDRL	Sum	%yld	S x %
J. californica	1.2	0.6	2.2	11.7	11.7	25.4	0.2	5.0
J. monosperma	0.7	0.5	9.0	7.1	14.1	31.4	0.3	9.4
J. angosturana	1.4	0.7	17.5	t	51.0	70.6	2.4	169.4
J. coahuilensis	1.1	0.5	18.4	-	17.4	37.4	1.6	59.8
J. pinchotii	3.6	1.6	12.0	4.2	38.6	60.0	0.2	12.0
J. arizonica	1.9	0.6	14.5	7.6	3.1	27.7	0.6	16.6
J. occidentalis	0.9	0.8	6.4	t	43.3	51.4	0.5	25.7
J. grandis	1.4	0.9	15.4	-	41.8	59.5	0.2	11.9
J. osteosperma	1.3	0.7	13.7	t	36.3	52.0	0.3	15.6
J. saltillensis	1.2	0.7	9.0	t	46.9	57.8	0.1	5.8
J. compacta	0.4	0.4	2.5	-	54.2	57.5	1.0	57.5
J. deppeana	7.6	2.0	9.1	12.0	25.7	56.4	0.3	16.9
patoniana	1.5	0.8	7.2	10.0	30.4	49.9	0.04	2.0
zacatacensis	4.1	1.4	10.3	16.0	1.3	33.1	0.5	16.6
robusta	3.9	0.9	6.3	15.6	2.0	28.7	0.7	20.1
gamboana	2.5	1.0	5.5	0.1	55.2	64.3	2.0	128.6
J. ashei	0.6	0.4	12.0	12.0	36.7	61.7	1.7	104.9
J. comitana	0.5	0.2	2.9	-	43.2	46.8	1.0	46.8
J. poblana	3.3	0.9	6.6	20.6	21.0	52.4	1.8	94.3
J. standleyi	2.6	1.2	10.3	25.2	2.8	42.1	3.4	143.1
J. jaliscana	2.6	0.7	7.6	10.0	1.1	22.0	1.4	30.8
J. monticola	1.9	0.9	14.3	7.0	10.4	34.5	0.7	24.2
J. flaccida	3.5	1.0	4.8	32.0	15.9	57.2	0.9	51.5
J. durangensis	1.2	0.9	7.9	5.0	21.9	36.9	0.2	7.4
J. martinezii	2.0	0.9	6.8	3.7	34.0	47.4	1.2	56.9